Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

A 31.3
R 31A
Cop. 2

ARS SPECIAL REPORT

U. S. DEPT. OF AGRICULTURE
LIBRARY
SEP 13 1961
CURRENT SERIAL RECORDS

Soybean Cyst Nematode

Progress in Research and Control

ARS 22-72

August 1961

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

FOREWORD

This is a situation report on the soybean cyst nematode--a destructive parasite first observed in this country in 1954 but since found in parts of eight States. It rounds up (1) progress in research to find better control methods, (2) extent and location of infestation revealed by surveys, and (3) quarantine regulations imposed and farming practices recommended to minimize nematode losses and prevent further spread of the pest.

This report was written for county agents, pest control workers, and other agricultural leaders to help them in answering general questions about the pest and its control and, more specifically, in developing and carrying out educational programs aimed at gaining informed support of farmers, handlers, and processors of agricultural products for regulatory activities and farming practices that will reduce individual losses due to this nematode and help hold the line against its further spread.

This report supersedes an ARS Special Report (ARS 22-29), Soybean Cyst Nematode, issued August 1956, which deals with the early history of this nematode in the United States and the first research and control measures to combat the parasite.

CONTENTS

	Page		Page
How the problem is being attacked. Research moving ahead on several fronts	2	Location and extent of infestation systematically hunted in surveys.	11
	2	Regulatory and control programs	15
Life history and habits of pest studied	3	Quarantine and quarantine regulations	15
Soil treatment	6	Federal-State cooperation	19
Rotation and other cultural practices	7	What agricultural leaders and individual farmers can do	19
Resistance	9	Outlook for nematode research and control	20

Information in this report was provided by the Crops Research Division and the Plant Pest Control Division of the Agricultural Research Service.

SOYBEAN CYST NEMATODE

Progress in Research and Control

The soybean cyst nematode (Heterodera glycines Ichinohe) has been positively identified from fields comprising a total of 60 thousand acres in parts of eight States. These States are North Carolina, Tennessee, Mississippi, Arkansas, Kentucky, Missouri, Virginia, and Illinois. The actual acreage presumed infested is several times the proved infestations. The reason for this difference is explained later in the section dealing with the location and extent of infestations (See page 11.)

Although the Nation's billion-dollar soybean crop is the most important among those threatened by this nematode, a number of other plants are susceptible in varying degrees to attack by the near-microscopic eelworm which penetrates and feeds on the roots of host plants.

The near-microscopic size of the nematode contributes to the difficulty of discovering and containing infestations. Even at its largest stages, the soybean cyst nematode is too small to positively identify on the basis of appearance alone without laboratory examination. As a result, it is impossible for a farmer or even a trained member of a nematode-detection survey team to simply walk into a field, pull up an infested plant, and positively identify the cyst nematodes on its roots. The male of the species is too small to see without magnification, being only about one-thousandth of an inch thick and one-twentieth of an inch long. In its earlier stages, the female is also microscopic but the mature female becomes visible to the naked eye after its body is distended with eggs. And upon death, its brown, egg-filled carcass looks like a speck of dirt.

Although the soybean cyst nematode can move only a few inches a year under its own power, the pest is easily spread by means of contaminated soil, bulbs, roots of plants, machinery, crops, or other articles from infested farms. And small populations of nematodes can build up rapidly to destructive proportions when conditions are favorable to their growth and reproduction--as when a vigorous crop of soybeans provides them with plentiful roots on which to feed. In fields where no soybeans or other host crops are grown, a small proportion of the larvae in the cysts can survive for long periods (probably 4 years or more) and start a new infestation if soybeans are again planted.

The characteristic symptoms of a nematode attack are yellowing and dwarfing of parasitized plants. For this reason, the disease condition caused by the parasite has sometimes been called by the descriptive name first given it in the Orient--"yellow dwarf." However, these yellowing and dwarfing symptoms are frequently absent with light infestations--and sometimes a heavy nematode population buildup can even be found late in the season on the roots of apparently healthy soybean plants.

The damage from soybean-cyst-nematode infestation varies widely--with density of the nematode population, age and vigor of the plants attacked, soil fertility, moisture, and other factors--from nearly total loss of the crop to no observable above-ground damage.

The absence of readily discerned symptoms and observable damage frequently accompanying light or otherwise retarded infestations has complicated the soybean-cyst-nematode problem: It makes it difficult to delimit infested areas, and farmers may not be properly forewarned of the damage to come.

The acreage known to be infested by the soybean cyst nematode is still less than one-fourth of one percent of the nearly 25 million acres planted to soybeans in some 30 States. However, losses caused by the pest in areas where it is established and the rapidity with which infestations can build up under favorable conditions indicate that the soybean cyst nematode could become a threat to all soybean-growing areas of the country if not held in check.

HOW THE PROBLEM IS BEING ATTACKED

The potential danger of the soybean cyst nematode, not only to growers in infested areas but to the country at large, became apparent soon after the pest was first observed in this country--near Castle Hayne, N. C.--in 1954. Consequently the research and regulatory facilities of the United States Department of Agriculture and affected States were called into action against the parasite. Prompt action was possible because Congress and the State legislatures had, as the need had arisen through the years, passed the basic legislation providing for a flexible regulatory-research program to fight new and old pests on a nationwide and local level.

War on the soybean cyst nematode is being waged along three major lines: (1) Research to discover more about the parasite and how it can be controlled most effectively; (2) extensive surveys to locate infestation; and (3) control measures, including quarantine of infested areas, regulations to prevent the nematode from spreading, and encouragement of farming practices designed to minimize the nematode threat.

Despite the considerable information yielded by nematode research, no practical method has yet been developed for eradicating the pest from infested fields. Therefore, the present aim of quarantine regulations and recommended farming practices is to prevent the spread of the soybean cyst nematode into uninfested areas and to help farmers with infested acreage minimize their losses.

At the national level, the Agricultural Research Service of the United States Department of Agriculture is responsible for co-ordinating nematode research and for administering interstate regulations to prevent the pest from spreading across State lines. In addition to participating in co-operative Federal-State research programs, affected States in some instances are conducting their own investigations on local aspects of the problem. And, as is always the case, the States are responsible for administering intrastate regulations to stop the pest.

RESEARCH MOVING AHEAD ON SEVERAL FRONTS

Although no simple solution to the soybean cyst nematode problem has yet been found, research during recent years has disclosed a considerable body of new knowledge which should aid in controlling the pest more efficiently.

Four major lines of investigation which have been pursued are: (1) Basic general information about the life cycle and habits of the soybean cyst nematode; (2) use of chemicals in nematode control; (3) effect of rotation and other cultural practices; and (4) development of nematode-resistant varieties of soybeans.

Status of research in these fields is reported in the following sections.

Life History and Habits of Pest Studied

One major line of attack on the soybean cyst nematode has been to study the life history and habits of the parasite and how it damages plants. This approach is aimed at discovering weak links in the parasite's life cycle and other basic facts which might point the way to more efficient control methods.

Although no quick, sure way of breaking the life cycle of soybean cyst nematode populations in infested fields has yet been developed, basic research has yielded helpful information. On the plus side, for example, studies comparing North Carolina and Tennessee nematodes showed no significant differences, thus indicating that only a single strain is involved. Previously it had been suspected that two nematode strains were involved because of the difference in field symptoms observed in the two States. Less encouraging was evidence that encysted larvae can survive in the soil for 4 years or longer in the absence of host crops without hatching and that small populations can build up quickly under favorable conditions when host plants are present. Several additional host plants have been identified in recent years by means of greenhouse checks at the North Carolina and Tennessee Agricultural Experiment Stations. Fortunately, however, a check of some 100 plants showed that the soybean cyst nematode is much more selective in its feeding habits than the root-knot and some other nematodes. Plants selected for checking included common crops and weeds of the regions in which the nematode has been found, plant species reported as hosts in Japan, and related plants. Additional details about some of the basic studies leading to these and other findings will be given in the following sections.

Life Cycle

Under summer conditions, the life cycle of the soybean cyst nematode requires about 30 days from egg to egg-producing female. Consequently the pest is capable of producing 3 or 4 generations in a season.

Emerging from the egg as a slender eelworm about 1/64th of an inch long, the larvae of the soybean cyst nematode penetrate the rootlets of soybeans and other host plants and feed on them. After developing through several stages, the larvae, now much larger, break through the outer layers of the root, but remain attached to it by the head and neck which remain embedded in the root tissue. At about this time the adult stage is reached and mating takes place. The fertilized female may produce 200 to 500 eggs. Some of the eggs are deposited in the soil and larvae developed in them and hatch within a few days. The larvae can immediately infect other soybean roots. The remainder of the eggs are retained within the lemon-shaped body of the female and remain there after she dies and her body has been converted to a cyst. This cyst has a brown, tough skin, highly resistant to decay and chemicals, which serves to

contain and protect the eggs. In the meantime, larvae have developed in the eggs in the cyst. A few of these hatch from time to time, but a small percentage can apparently survive for as much as 4 years or more without hatching.

Viability Span of Eggs and Larvae Affected by Moisture Conditions

How long free and encysted eggs and larvae can survive under varying conditions has important implications in the testing and refinement of methods for controlling the soybean cyst nematode. Therefore, considerable research is being done to uncover this basic information.

Controlled experiments and field tests at the North Carolina and Tennessee Agricultural Experiment Stations show that encysted eggs of the soybean cyst nematode may, under favorable conditions, survive in the soil without hatching for 4 years and possibly longer.

Fortunately, however, encysted larvae and eggs are susceptible to desiccation and cannot survive as long in dry storage as in the soil. Knowing precisely how long the larvae can survive in storage would make it easier to avoid the danger of spreading the pest through seed sold for planting, should the nematode make its way into a commercial seed-producing area. But the ability of encysted larvae to survive in storage varies widely with the moisture conditions prevailing, as shown by recent studies by ARS nematologists located at the Tennessee Agricultural Experiment Station. In one controlled experiment with soybeans stored under conditions of extreme dryness (induced by the use of sulfuric acid), no larvae survived after a month. In a second experiment, at a relative humidity of 89 percent, no larvae survived after 6 months. But in a third experiment, some larvae survived for 10 months when stored in a garage without humidity controls. Because soybeans are not normally kept in storage for more than 8 months before being sold for planting, storage--under conditions prevailing in the last experiment--could not be depended on to eliminate any nematode hazard.

Temperature Affects Nematode Activity

Cold inhibits activity of the nematode. While exact information on this point is lacking, there is probably little activity of any kind below about 45° F. However, larvae in cysts can probably survive even the coldest of outdoor winter soil-temperatures. Extreme heat also may have an adverse effect on the soybean cyst nematode. A recent experiment with young soybean plants inoculated with nematode larvae shows that, when the temperature is above 88° F., the reproduction is lower than at temperatures below 88°.

New Host Plants Discovered

Important for detecting and controlling the soybean cyst nematode is the ability to recognize plants capable of serving as hosts--that is, plants on which the parasites can reproduce. For this reason, Federal and State researchers at the Tennessee Agricultural Experiment Station checked more than 100 plants for susceptibility. Four new host plants, identified as a result of this systematic check, are: Hemp Sesbania, a common weed found most frequently in low-lying fields along the Mississippi River

where it is locally known as the coffee bean; white lupine, a winter crop in the South; henbit deadnettle, a winter annual found in waste and cultivated land; and the mung bean.

Prior to discovery of these additional host plants, nine other hosts besides the cultivated soybean (Glycine max) had been identified--some of them in the Orient before the soybean cyst nematode was observed in this country. The other, previously identified hosts are: Two additional species of soybeans (G. ussuriensis or wild soybean and G. gracilis); the adzuki bean; snap bean; common and hairy vetch; and three kinds of lespedeza--annual, common, and sericea.

With a single exception, all of these 14 plants comprising the list of known hosts to the soybean cyst nematode are legumes. The one exception is henbit deadnettle which is a weed of the Labiatae family.

The soybean continues to be by far the most important host to the nematode, because of its greater receptivity to the parasite, and because of the large acreage grown and its great economic importance. The nematode does not reproduce as prolifically in other host plants tested and they are not grown on as large a scale. Hence, ARS pest control workers have focused their nematode detection alert primarily on soybean-growing land.

Not all plants that are invaded by the parasitic organisms are true host plants. Some plants that are attacked by the soybean cyst nematode either do not permit the pest to reproduce or inhibit reproduction by preventing a large portion of the females from maturing. Such plants are referred to as trap plants because they entice the parasitic larvae into an environment unfavorable for nematode reproduction.

How the Nematode Causes Damage

Feeding of the soybean cyst nematode on the roots of plants causes local damage to the root system. The root tissue is distorted and heavily attacked roots are much smaller than normal roots, with a correspondingly reduced ability to take up water and nutrients from the soil. In highly fertile soil with plenty of moisture, noticeable symptoms of disease may not appear. In less fertile soil or with reduced water supply, the plants may show signs of nutrient deficiency or water stress, becoming yellow or stunted. In heavily infested fields, when moisture is deficient in the growing season, the stand of soybeans is often poor with many yellowed and stunted plants in the surviving crop. This results from a heavy attack on the young plants in their most vulnerable state. If subject to only a light attack at this time, the young plants may show no marked damage, however. And later in the season when the plants are better able to withstand attack, even heavily attacked mature plants may show little damage.

How the Parasite Is Spread

The soybean cyst nematode is a soil-borne pest. Although it can move only a few inches a year on its own, the nematode could easily be carried long distances in a short time through the movement of soil containing cysts and larvae.

Only a limited number of plants are attacked by the soybean cyst nematode. However, all plants grown on infested soil may transport the pest unless they are either protected from contamination or are cleaned to remove the cyst-carrying soil. Nursery stock and other plants with roots attached, bulbs, corms, and rhizomes are particularly likely to harbor the pest if they are not properly cleaned or treated. Hay, small grains, cotton, corn, peanuts and other crops may also be contaminated with small particles of nematode-containing soil. Harvesting machinery, other farm equipment, and vehicles, bags, and other containers which have been contaminated with infested soil can likewise carry the parasite, if they are not thoroughly cleaned. Farm workers and livestock may also transport the nematode in soil particles clinging to them. Other, less controllable, ways in which the nematode may sometimes be spread are wind, water, wild animals, and birds. In short, any means capable of moving even small amounts of infested soil is a potential danger source.

Soil Treatment

Fumigation

Soil fumigation has proved its value for protecting some high-value crops against attack from various species of nematodes. For example, it is profitably used in growing flue-cured tobacco on land infested by the root-knot nematode.

Soybeans, however, are a relatively low-value crop. Consequently, an individual soybean grower cannot afford to spend as much per-acre on nematode control to increase his crop yields as can a tobacco grower. And fumigation costs are still too high to be economically practicable for the individual soybean grower.

Further aggravating the problem, present techniques do not yet fully assure that all the larvae in infested fields will be killed, although all commercial nematocides are effective in reducing soybean-cyst-nematode populations rapidly by 90 or 95 percent. Also, a small nematode population left over after fumigation can build up rapidly on the vigorous soybeans grown in newly fumigated soil.

Use of fumigation as part of a national or community program to eradicate a pest or stop it from spreading into uninfested areas is different from its use by an individual farmer whose sole purpose is to hold down the nematode population sufficiently to produce a good crop. If a small soybean-cyst-nematode infestation should be found in or near a heavy soybean-producing area, for example, a high per-acre expenditure for fumigation might be a small expenditure in terms of total savings to the billion-dollar soybean industry. Such was the reasoning behind the prompt measures taken after an infestation was found on a 20-acre tract in Illinois. The land was fumigated and taken out of soybean production to minimize the danger of the pest's spreading further in this heavy soybean-producing State.

Soil Irradiation Not Practical

Among the possibilities which have been investigated for controlling nematodes in the soil and as contaminants of nursery plants, seed, bulbs,

and other kinds of planting stock is the use of ionizing radiation. Nematodes were found to be so resistant to radiation that the use of this method would require radiation sources of completely impractical size to be of any value at all. (Although exposure of 600 roentgens are lethal to man, nematodes can survive exposures of more than 100,000 roentgens.)

Rotation and Other Cultural Practices

Rotation For Control of Nematodes in Infested Areas

Crop rotation--following a soybean crop with a 1-to-5-year rotation of a nonhost plant--is the most practical means now available to individual growers for holding down soybean cyst nematode populations in infested fields. Shifting periodically from soybeans to nonhost plants is also recommended as a precautionary measure to growers, particularly in fields adjacent to infested areas. Experience has shown that it is much easier and cheaper to keep land free from the nematode than to control the pest after it has become established.

Growers with infested land can reasonably expect to have a good crop of soybeans following a 2 or 3 year rotation to nonhost crops but will be inviting crop failure if they attempt to grow soybeans 2 years in succession. The reason for this is that the small remaining population of nematodes will build up on the first soybean crop but attack it too late to cause any damage. At the end of the summer the soil will have many fresh cysts with larvae ready to attack the next crop early in the season.

For growers faced with the need to shift from soybeans because of a nematode infestation, the problem of finding nonhost plants for alternate cropping is fortunately much less difficult than with certain other pests. The root-knot nematode, for example, attacks a much wider variety of plants and so narrows the choice of alternate crops which can be used in combating it. Nearly all row crops, including cotton, corn, and sorghum, have been found to be nonhost plants for the soybean cyst nematode. However, the problem of shifting to alternate crops is complicated by a number of factors, such as the trend towards specialized farming and heavy investment in equipment for one type of farming, marketing problems, and, in the case of some alternate crops, acreage allotments or low net return.

Effectiveness of rotation for reducing nematode populations and for increasing yields from soybeans grown on infested land has been demonstrated. In North Carolina, soybeans grown on infested soil following a 3-year rotation with a nonhost plant produced yields 10 times larger than yields from land continuously planted to soybeans. After a 2-year rotation of a nonhost crop, soybean yields were 5 times greater than when soybeans were produced continuously.

It would be unrealistic to expect that similar increases would result everywhere from rotating soybeans with nonhost crops, however. Other variables, in addition to the density of the nematode population (which rotation aims at reducing), affect damage resulting from the pest. For example, a severe infestation of soybean cyst nematodes would result in heavier damage to plants grown in marginal soil or under droughty conditions than where the land is more fertile or moisture conditions more favorable. Consequently, a reduction in the soybean-cyst-nematode

population through crop rotation could not be expected to result in as great an improvement in areas with favorable growing conditions as in areas where less favorable conditions prevail.

Although yields of soybeans are increased the first season following the alternate crop, this benefit does not carry over to the second successive planting of soybeans. In fact, there is some evidence that planting to an alternate crop can have adverse effect on yields from the second of two successive years of soybean plantings immediately following the nonhost crop.

In Tennessee experiments rotating cotton and soybeans on heavily infested soil, soybeans grown immediately after cotton produced about 33 bushels per acre, as compared to approximately 23 bushels per acre grown on land planted continuously in soybeans. But the following year, when all plots were planted in soybeans, production dropped to only a little more than 5 bushels per acre on plots that had been in cotton 2 years earlier as compared with nearly 22 bushels per acre on plots that had been planted continuously in soybeans.

Other host crops in addition to soybeans--vetch, snap beans, lespedeza, white lupine, and the mung bean--should, of course, be avoided in a rotation, since they would also harbor the parasite and defeat the purpose of the crop shift. For the same reason, it is important to keep rotating fields free of volunteer soybeans or other host plants.

Value of Rotation as a Preventive Measure

Advantages of using rotation on presumably uninfested or lightly infested land as an insurance against the pest's becoming established is stressed by ARS pest-control workers. They point out that planting to a nonhost crop tends to reduce the size of any infestation centers that may exist by cutting down the nematode population--and so decreases the chances that cysts will be carried by machinery or other means to start new centers of infestation throughout the farm. Continuous planting of host crops, on the other hand, permits points of infestation to grow without interruption, thereby increasing the probabilities of extensive spread. If rotation to a nonhost crop is postponed until the originally small infestation has grown and been spread, there will be many points of infestation to cope with instead of one--and the chances of stopping the pest reduced.

Trap Crops

Use of trap crops instead of rotation to ordinary nonhost crops has been suggested as a possibility for hastening the process of reducing the nematode population in infested fields. Scientists in Japan, for example, are investigating the possibility that the kidney bean, once considered a host plant to be avoided in rotation, may be useful for this purpose. However, there is not yet sufficient evidence to prove that trap crops are appreciably more effective than ordinary nonhost rotation crops.

Replanting of Nematode-Damaged Soybean Field Not Advised

Replanting fields where soybeans are stunted by heavy soybean-cyst-nematode infestation and unfavorable weather at the start of the growing

season is not recommended for increasing yields. Present evidence is that replanting under such circumstances will actually reduce yields. This was indicated by a recent ARS-Tennessee experiment. To measure the effect of replanting, part of a stunted soybean crop growing in an infested experimental field was plowed up and replanted, while the remainder of the crop was allowed to grow in another section of the field without replanting. Yields from the replanted area were only 8.4 bushels per acre, as compared to 28 bushels per acre from the section which was not replanted.

Resistance

Development of resistant soybean strains combining other desirable qualities and suited for growing in different parts of the country is still in the offing. However, ARS scientists feel that this possibility holds the best long-term promise of controlling the soybean cyst nematode--and that, within a few years, resistance may be successfully transferred to one commercial variety suitable for growing in about 90 percent of the infested area.

Research has already made considerable progress in this direction despite the complexity of the problem facing plant breeders working on the project.

Three major steps in this research are reported here briefly: Location of resistant breeding stock in existing varieties; the painstaking process now under way of transferring resistance to adapted varieties; and progress and plans for increasing seed from a backcross between a resistant genotype and one commercial variety for testing and possible release to farmers.

Location of Resistant Breeding Stock in Existing Varieties.--In 1957, ARS researchers announced that they had located 3 highly resistant types by the process of evaluating more than 3,000 varieties comprising USDA's international germ plasm collection. The resistant types were: Peking, PI 84751, and PI 90763.

Ordinarily a resistant variety is one that can thrive and produce good yields in the presence of a parasite but does not support its reproduction. Although damaged by the soybean cyst nematode, resistant soybean varieties are not as severely damaged as are susceptible ones. For example, the resistant types will ordinarily produce an acceptable yield under conditions that would result in total crop loss in susceptible types. The big advantage in using resistant varieties is that the nematode population will be progressively reduced in succeeding crops.

Theoretically a resistant variety could be either one that the soybean cyst nematode does not attack or one which it invades but which does not enable the parasite to reproduce. All 3 varieties discovered in the original survey of germ plasm and plants bred from these resistant genotypes belong to the latter category; they are invaded by the nematode but inhibit its reproduction.

Plants with the ability to produce a good crop despite a soybean-cyst-nematode invasion but which enable the parasite to reproduce are sometimes mistakenly referred to as being resistant or having resistance to the soybean cyst nematode. Actually such varieties are tolerant rather than resistant--and their ability to support reproduction of the parasite tends

to increase the nematode population rather than decrease it. For these reasons, resistant plants, rather than tolerant ones, were the target of the search for suitable breeding stock.

A difficulty that had to be overcome in evaluating the degree of resistance of various soybean types was the wide variation in density of nematode populations infesting different parts of a field. This problem was solved through double-row planting--placing a readily recognizable check plant of known susceptibility beside each test plant. The standard check plants provided a good index of the density of the soybean cyst nematode population surrounding the test plant with which it was paired.

The Painstaking Process Now Underway of Transferring Resistance to Adapted Varieties.--Since none of the three resistant types located in the survey of existing varieties was suitable for commercial production, work was immediately started on breeding new types combining resistance with high yield and other desired qualities. The task of developing resistant strains to meet requirements of growers in different sections is, however, complicated by the fact that resistance to the soybean cyst nematode is inherited by a very complex process.

Studies by ARS and State plant breeders and nematologists indicate that resistance to the soybean cyst nematode is transmitted in soybeans by means of three independent recessive genes. On the face, this would mean that in the F_2 generation (second generation of descendents from the parent stock), only 1 out of 64 plants can be expected to be resistant. Under actual conditions prevailing in the current soybean breeding project, the chances are more heavily weighted against getting a resistant bean in a backcross--more like one out of 150. This is because, in the original study of the inheritance of resistance, a resistant plant was defined as one on which no more than one nematode was found, whereas in breeding new varieties only those with no soybean cyst nematodes are considered resistant.

With the complex inheritance of resistance to the nematode, at least 3 generations of plants must be grown to complete one backcross. To speed up the search for resistant plants, scientists worked up a schedule for growing three generations in one year--one generation in the field and two in the greenhouse.

All three types originally found to be resistant have been crossed with adapted varieties. Most work at present is centered on crossing the Peking with varieties adapted to the needs of farmers in different areas.

Breeders are using the backcross method--the simplest breeding technique for developing resistant varieties--because of the complexity of the task of transmitting resistance. In backcrossing, the goal is simply to add only one desired characteristic to an adapted strain and eliminate all the other undesired characteristics from the second plant, rather than to attempt to breed in other improvements. In this case, the object is to transmit the resistance of the Peking to an adapted commercial variety while maintaining the other characteristics of the adapted variety. Three separate breeding projects are under way.

Progress and Plans for Increasing Seed from a Backcross between a Resistant Genotype and One Commercial Variety for Testing and Possible Release to Farmers.--A cooperative ARS-State breeding project at the North Carolina Agricultural Experiment Station aimed at incorporating

resistance of the Peking into the variety Lee is furthest along the way. The third backcross has been completed and the supply of seed will be increased in 1961 for testing and possible release. The Lee is adapted to growing conditions in North Carolina, Mississippi, Arkansas, and other States comprising about 90 percent of the infested area. When it has been successfully developed and tested, the resistant Lee is expected to have the characteristics of the Lee plus resistance.

A second breeding project is being conducted cooperatively by ARS and the Mississippi and Tennessee Agricultural Experiment Stations to backcross the Hill (a variety adapted to Tennesse, Kentucky, Mississippi, Iowa, Missouri, North Carolina, and Arkansas) to the Peking.

The third Federal-State cooperative breeding project is being conducted by the Missouri Agricultural Experiment Station, with assistance from the Tennessee Agricultural Experiment Station. This project is concerned with backcrossing the Peking with the varieties Clark and Scott, adapted to Missouri and Illinois.

When the soybean breeding experiments were started, the goal was to breed resistance into a wide variety of soybeans. But since the difficulty of the task has been demonstrated, efforts have been concentrated on breeding resistant varieties for infested areas only.

Should the need ever arise for a resistant soybean with different qualities than those now being developed, using the resistant Lee rather than the Peking as a source of resistance would give plant breeders a head start in developing the new variety. There would be a disadvantage in using the Peking because it has undesirable characteristics. It has susceptibility to disease, tendency toward low yields, black seeds, and tendency of the seeds to shatter.

LOCATION AND EXTENT OF INFESTATION SYSTEMATICALLY HUNTED IN SURVEYS

Locating existing infestations in order to contain or eradicate them is basic to the control of any plant pest. This is no easy task, even with pests that can be readily seen and recognized and which consistently induce characteristic symptoms or cause damage that makes their presence quickly known. Promptly locating and delimiting infestations is even more difficult in the case of an insidious pest like the soybean cyst nematode. In most stages this nematode is too small to be seen with the naked eye and cannot be identified without magnification even in its largest stages--either as the egg-filled body of the female or its larvae-distended carcass. Further complicating the problem, the characteristic symptoms of yellowing and dwarfing are not always present in infested fields to help alert farmers and pest-control workers to the parasite.

Without a systematic approach, locating a small, isolated nematode infestation on the nearly 25 million acres planted to soybeans would be like finding a needle in a haystack. ARS plant-pest-control workers have developed efficient survey techniques through long experience in tracking down elusive pests.

Experience has shown that soil sampling is the most reliable method of surveying for the soybean cyst nematode, so ARS pest-control workers place primary reliance on this technique. Other methods, such as plant

pulling or symptom checking of fields, are also used to supplement soil sampling in cooperative surveys conducted by ARS and the States whenever circumstances warrant. Low-flying planes have been effectively used to cover a wide territory with a quick look-see for telltale signs of nematode damage. Airplane observers carry a map showing soybean acreage and mark down fields showing suspicious symptoms for follow-up soil sampling.

Two general types of surveys--both employing soil sampling--have been developed for finding soybean-cyst-nematode infestations: (1) Broad exploratory surveys to detect new areas of infestation; and (2) more intensive surveys to delimit areas known to be infested.

Detection Surveys

Detection surveys are used in areas not known to be infested by the nematode. Their objective is to provide the widest possible coverage of soybean-growing areas with the manpower and time available.

Since it would obviously be impractical to inspect all the country's farm land, detection surveys are planned to provide a representative sampling of the acreage. And sampling priorities are given to fields most likely to have an infestation. These soybean-cyst-nematode danger spots are: (1) The oldest soybean production areas; (2) fields that have been continuously planted to soybeans or other host crops; (3) acreage on which symptoms of yellowing and dwarfing have been reported; (4) fields that have been taken out of soybean production because of unexplained crop failure; and (5) fields that have grown soybeans or other host crops in rotation.

Delimiting Surveys

After a soybean-cyst-nematode infestation has been found in a new area, its presence confirmed by a resurvey, and the identification concurred in by the Nematology Investigations Unit, Crops Research Division, ARS, Beltsville, Md., the next problem is to find the outer limits of the infestation. Delimiting surveys, employing more intensive checking methods, are used for this purpose. To speed up the check, a random, exploratory survey of the adjacent area is first conducted. Then if no new infestation is found, fields adjacent to the infested property are sampled in a grid pattern to assure random and systematic sampling of the soil. Next, fields a mile distant are sampled in a grid pattern but at wider intervals.

Soil samples are packed in individual paper bags so that soil from one location will not become contaminated or contaminate soil from another farm. The bags are marked to maintain the identity of each soil sample and are sent to a local USDA - ARS or State laboratory station for washing the samples to see if they contain nematodes. If cysts are found, they are placed in a preservative, properly labeled, and forwarded to a center for official identification.

Despite great difficulties involved in detecting a pest as insidious as the soybean cyst nematode, the survey system has helped in discovering numerous centers of infestation which could easily have gone unnoticed for many years with serious results.

States known to have infested areas, the date infestation was first observed in each State, and the number of counties and the acreage known to be infested are given in table 1.

Table 1.--Known distribution of the soybean cyst nematode, as of June 30, 1961.

State	Year first observed	Counties	Acres
North Carolina	1954	9	5,764
Tennessee	1956	9	14,583
Mississippi	1956	1	42
Arkansas	1957	6	10,234
Kentucky	1957	2	3,298
Missouri	1957	6	12,119
Virginia	1958	3	14,155
Illinois	1959	1	20
Total		37	[1] 60,215

[1] Figures in this column represent acres infested from beginning of program through June 30, 1961.

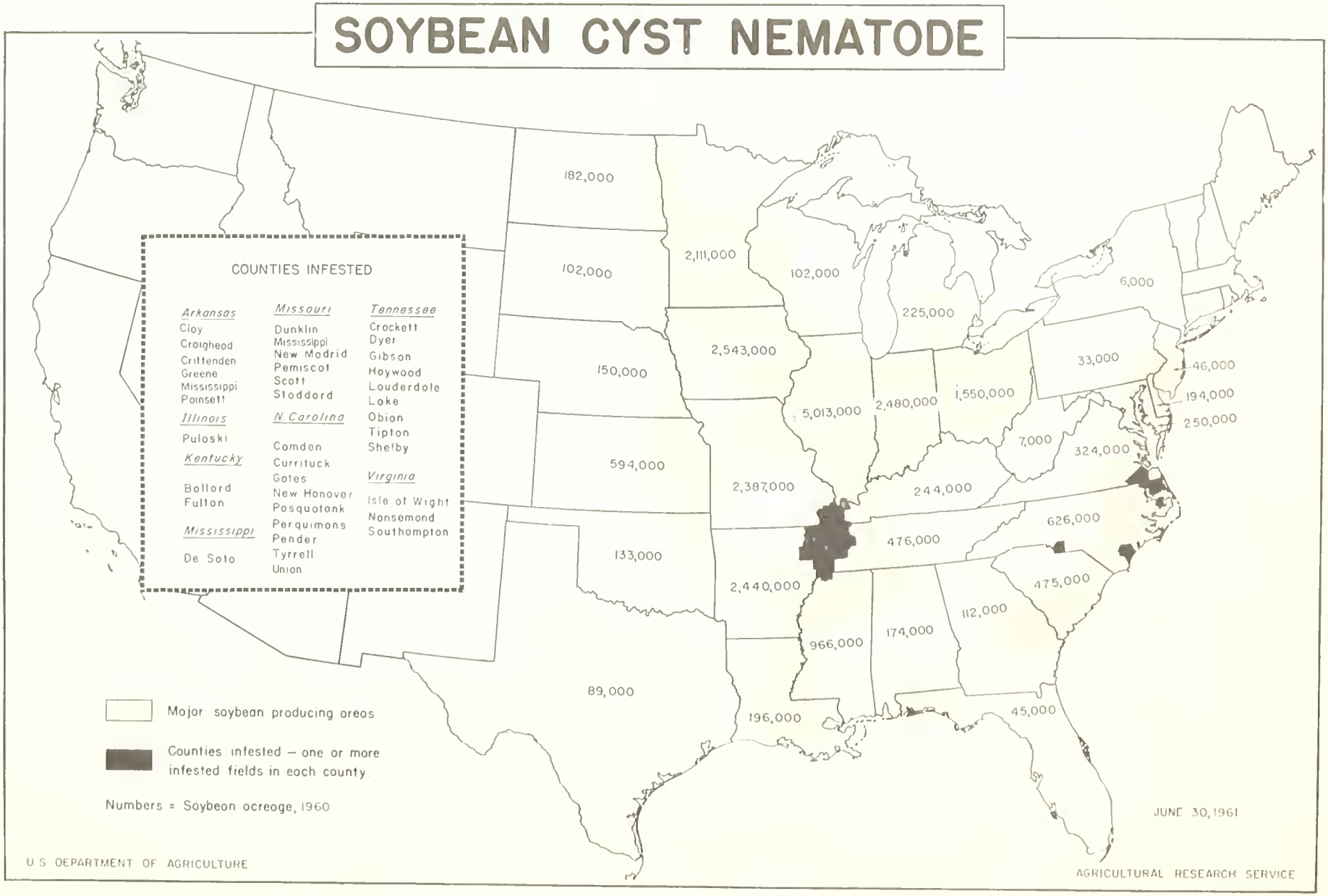
Although the figures on the acreage proved to be infested by the nematode give some indication of the extent of the problem, they are not an accurate measure of the acreage actually infested. In some heavily infested areas, for example, the acreage actually infested may be several times that checked and found to be infested. In northwest Tennessee, northeast Arkansas, and southeast Missouri extensive areas were presumed infested and regulations promulgated as soon as surveys revealed a continuous pattern of heavy infestations, even though only a small percentage of the fields were actually surveyed. Thus, funds and manpower were conserved for more intensive surveys on the periphery of the infestation. Since the practical purpose of surveys is to locate and contain nematode infestation, it was deemed unnecessary to demonstrate infestation on every property. For this reason, the total infested acreage in the United States, particularly in the upper Mississippi delta area, is presumed to be much higher than the 60,000 acres proved to be infested.

Distribution and extent of the infestation suggest that the soybean cyst nematode has been in this country at least 10 to 15 years, although it was first observed in 1954. The wide geographic separation between infested areas along the Mississippi and those in North Carolina and adjoining States also suggests that the infestations are not connected. The accompanying map (Page 14) shows the location of areas known to be infested.

Despite the discovery of the soybean cyst nematode in parts of eight soybean-growing States, no evidence of infestation has been uncovered in the heaviest production areas of the country. Early detection of the pest has enabled farmers in infested areas to take steps to minimize the nematode damage while growers in adjacent areas are alerted to the need to guard against the parasite.

Containment of the soybean cyst nematode is highly important because of its great damage potential, the ability of nematode populations to build up quickly, and the lack of practical methods for eradicating nematodes from infested fields. This in turn emphasizes the need to continue searching for new infestations, to delimit existing infestations, and to halt their spread into uninfested areas.

SOYBEAN CYST NEMATODE



DN-1978

REGULATORY AND CONTROL PROGRAMS

The fight against the soybean cyst nematode is being carried to the fields and farms of America in a two-pronged attack by: (1) Quarantine regulations to prevent the pest from spreading; and (2) recommended farming practices by which the farmers in uninfested areas can protect themselves against the parasite and those with infested acreage can reduce their losses and the danger to other farmers by holding down nematode populations.

Both the quarantine regulations and the recommended control measures utilize the latest scientific know-how for checkmating the soybean cyst nematode. Both the regulatory and control programs center their attack on known infested areas and adjacent farming sections most liable to exposure.

Success of any regulatory or control program depends on public understanding and compliance. The soybean-cyst-nematode program calls for across-the-board participation by all interested groups in the fight against the pest. Federal and State pest-control authorities cooperate and work closely with farmers and everyone concerned in harvesting, handling, or processing soybeans and other articles that might carry the nematode.

Growing awareness of the nematode problem has already been demonstrated. For example, county agents, individual farmers, and other interested persons have reported yellowing and dwarfing symptoms and unexplained crop losses to pest-control authorities, thus aiding in the systematic search for infested areas.

Discovery of the rather extensive infestation has magnified the need for effective regulation and control programs. This in turn has increased the importance of the role of the county agent and other agricultural leaders in answering questions about the parasite and developing educational material in support of regulations and farming practices to control the soybean cyst nematode.

The following sections give the battle plan of the front-line fight against the soybean cyst nematode in more detail. These sections briefly report on: (1) Quarantine and quarantine regulations; (2) Federal-State cooperation in fighting the soybean cyst nematode; and (3) what educational leaders and individual farmers can do to help control the nematode.

Quarantine and Quarantine Regulations

Containment of the pest is particularly important at the present stage of the war on the soybean cyst nematode because (1) no practical means has yet been found for eradicating the parasite from infested fields, and (2) resistant varieties of soybeans with desirable commercial characteristics are not yet available. So long as these conditions prevail, it will be much easier and less costly to prevent the pest from spreading than it would be to let the nematode spread and try to live with it. Fortunately, the soybean cyst nematode can spread only a few inches a year on its own power--and so cannot move long distances in a short time unless carried.

Quarantine regulations are designed to prevent the parasite from hitching a ride into nematode-free areas by means of contaminated soil,

products, machinery, or other articles. Now in parts of eight soybean-growing States, the pest could easily be spread throughout these States and into the other 23 soybean States, if not stopped by adequate safeguards.

Federal quarantine regulations provide pest-control safeguards at the interstate level; State regulations safeguard against the parasite's spreading within the State borders.

Federal Regulatory System

The Federal government is responsible for establishing and enforcing Federal quarantines and regulations to prevent the interstate spread of plant pests.

Federal regulations prohibit the interstate movement from regulated areas of articles or products that might harbor the soybean cyst nematode, unless they are accompanied by an official certificate or permit indicating that the articles are free of the pest or that safety requirements have been complied with.

How Quarantines Are Imposed.--When evidence of a soybean-cyst-nematode infestation is found for the first time in a State, a public hearing is held by ARS pest-control authorities with State regulatory officials, farmers, and other interested parties in attendance. Following consideration of all relevant information, the State may be placed under quarantine.

Regulated Areas.--Only those parts of the State in which a hazard of spread exists are designated as regulated areas. Where a single farm or a few isolated fields are found to be infested, regulation may be applied on a property basis. But where a number of infested properties are found close together, it is generally necessary to place the whole area under regulation. Where the infestation is widespread, an entire county or political subdivision may be placed under regulation.

Regulated Articles.--The following articles, unless exempted by administrative instructions, are prohibited from moving interstate from regulated areas without certification to show that the shipment has been produced or handled to prevent infestation or has been treated to destroy the pest:

> (1) Soil, separately or with other things; (2) nursery stock and other plants with roots attached; (3) true bulbs, corms, rhizomes, and tubers; (4) root crops; (5) soybeans; (6) small grains; (7) ear corn; (8) hay, straw, fodder, and plant litter of any kind; (9) seed cotton; (10) used farm tools, implements; (11) used construction and maintenance equipment; (12) used crates, boxes, burlap bags, and cotton picking sacks, and other used farm-products containers; and (13) other farm products and farm equipment, processing machinery, trucks, wagons, railway cars, aircraft, boats, and other means of conveyance and (14) any other products or articles determined to present a hazard.

However, most of the regulated articles can be moved from regulated areas, provided compliance with approved handling, sanitation, and treatment practices has made them safe for interstate shipment.

Exemptions from Certification Requirements.--When the following articles have been produced, harvested, or handled as indicated, certificates are not required for interstate movement:

(1) Root crops, such as turnips, carrots, and sweet potatoes may be moved to a designated processing plant. Or, if washed free of soil or treated to the satisfaction of the inspector, such root crops may be moved through ordinary produce markets to the tables of consumers.

(2) Soybeans may be moved directly to a designated oil mill or storage facility for approved processing or uses other than planting, provided the beans and their containers did not come in contact with the soil during harvest or handling.

(3) Small grain which did not come in contact with the soil or soil-contaminated containers in harvesting may be moved directly to a designated storage facility for uses other than planting.

(4) Ear corn, harvested from the stalk and placed in a wagon or truck without coming into contact with the soil, may be moved directly to storage or other handling facility.

(5) Hay, straw, fodder and plant litter of any kind may be moved from regulated areas only when harvested and handled so that they will not, in the judgment of the inspector, transmit infestation.

(6) Seed cotton may be moved to approved gins.

(7) Used tools and implements, when washed, steam cleaned, air cleaned, or otherwise treated and thereafter protected from infestation, to the satisfaction of the inspector, may be moved from regulated areas.

(8) Cotton picking sacks may be moved when they have been cleaned to the approval of the inspector.

(9) Trucks, wagons, railway cars, aircraft, boats and other means of conveyance previously determined to constitute a soybean-cyst-nematode hazard may be moved from regulated areas provided they have been treated to the satisfaction of the inspector.

Information regarding designated processing plants, oil mills, storage facilities, and gins to which regulated articles may be sent under limited permit may be obtained from the local ARS pest-control inspector.

Certificates and Limited Permits.--Unless exempted by administrative instructions, all regulated articles moving interstate from regulated areas must be accompanied by either a certificate or a limited permit. Certificates may be issued only when the inspector determines the articles are safe for shipment into nematode-free areas. Certificates may be issued under the following conditions: (1) When the inspector judges that the articles have not been exposed to infestation; (2) when he has examined and found them free of infestations; (3) when the articles have been treated to destroy infestation by officially approved methods under observation of the inspector; or (4) when they are grown, produced, manufactured, stored, and handled so that no infestation would be carried by them.

Provisions affecting the movement of soybeans and other regulated articles are formulated and administered to impose the least possible burden while safeguarding everyone concerned. Pest-control experts have analyzed the production, harvesting, handling, and processing of soybeans and other crops affected by the soybean cyst nematode to provide a sound basis for drafting regulations that do the job effectively with minimum inconvenience.

While setting up essential safety standards, the regulatory program is flexible in its application. This enables the program to take prompt advantage of new research findings which would either contribute to more efficient nematode control or would safely permit a relaxation of requirements. A case in point relates to the handling of corn from infested areas.

Soon after the soybean cyst nematode was first discovered in North Carolina, it was found that when an infested field was rotated from soybeans to corn, the latter crop could also be a source of infestation. The harvesting practice there, at that time, was for pickers to snap off the ears and throw them on the ground, where they could become contaminated.

The solution to this problem was to write into the regulations a provision, allowing the corn to move from an infested farm if the corn is thrown into a truck or wagon without touching the ground. Before moving from the premises, the wheels of the vehicle must be cleaned thoroughly so that they will not carry contaminated soil. This eliminates the hazard of spreading the soybean cyst nematode and costs the grower very little.

Another example was the handling of a shipment of new potatoes from a farm found to be infested with the nematode just as the crop was being harvested. Since there was no local market for the potatoes, the problem resolved itself into the question of whether (1) a way could be devised to market the crop interstate without danger of spreading the nematode; or (2) the potatoes would have to be left on the farm to spoil. Pest-control experts investigated the circumstances and came up with a practical solution which safeguarded farmers in other States without working a hardship on the potato grower. After conferences with State officials, the potato-marketing association, and the transportation company involved, Federal pest-control authorities ruled that it would be safe to ship the potatoes, after washing to remove dirt, in new paper bags, for consumption in cities at a distance from other potato-growing sections of the country.

Intrastate Regulation--A State Responsibility

When a Federal domestic plant quarantine has been established the State governments are legally responsible for State quarantine and intrastate regulations to keep plant pests from spreading within their borders. States without nematode infestations have a big stake in keeping out the pest and are protected by Federal quarantines. And States with infested areas have a big stake in preventing the pest from spreading further within their borders.

When a Federal quarantine is imposed on a State because of a soybean-cyst-nematode infestation, only the areas officially determined to be infested or exposed are placed under regulation. However, this limitation is conditioned upon the affected State's providing and enforcing the same regulatory safeguards on the intrastate movement of regulated articles as are currently required for interstate movement. If adequate safeguards

were not provided on intrastate movement of regulated articles, the entire State could be exposed and therefore subject to interstate regulation.

Federal-State Cooperation

Besides working closely together in administering regulations to prevent the soybean cyst nematode from spreading, the Federal government and individual States have joined forces on other fronts of the fight against the pest.

State pest-control authorities cooperate with ARS survey teams in locating and delimiting infestation centers. States also cooperate in Federal-State research projects aimed at refining present weapons for combating the nematode or discovering new ones. And some States are conducting their own research on local aspects of the soybean-cyst-nematode problem. For example, States, where a great varieity of crops are grown for interstate shipment, are interested in developing methods of handling, harvesting, and treating such crops so that they can be safely moved interstate, should the farms where they are grown become infested. Present regulations permitting peanuts, cotton, and other regulated articles to move from regulated areas, provided safety requirements are met, are based on such studies, conducted by ARS and the States.

The cooperative Federal-State approach to the soybean-cyst-nematode and other pest-control programs recognizes that pests do not respect State or other political boundary lines--that everyone is concerned, and the task of controlling them is too big for any one group or jurisdiction working alone.

What Agricultural Leaders and Individual Farmers Can Do

Success of the soybean-cyst-nematode program--like all pest control programs--depends on full compliance with regulatory safeguards and widespread use of practices recommended to control the pest.

This faces county agents, pest-control workers, officials of growers associations, and other agricultural leaders with an opportunity and responsibility to help alert the man on the farm, or in the truck, at the storage facility, or at the processing plant to the soybean-cyst-nematode problem and to what individuals can do to help combat the pest.

Some of the ways in which individual farmers and others can help contain the soybean cyst nematode are summarized in the following section:

(1) Farmers can help locate undiscovered infestations on their property by learning to recognize the symptoms of yellowing, stunting, and reduced yields and reporting suspicious symptoms or unexplained crop losses to their county agents or pest-control authorities.

(2) Farmers with infested land should rotate from soybeans and other host crops to nonhost crops for 3 or more years, if possible. Host crops should never be grown 2 years in succession on infested soil.

(3) Growers in free areas should insist that only cleaned equipment should come on the farm.

(4) Growers should insist on cyst-free seed.

(5) Soybean growers are advised to rotate to nonhost crops whenever this is economically possible. The longer a field is planted continuously in soybeans or other host crops, the more likely it is to become infested.

(6) Everyone should guard against moving soil, even in small amounts, from infested farms. Farmers should wash their shoes thoroughly after walking through muddy fields that may be nematode infested; crops should be harvested so as not to be contaminated by infested soil; trucks should be washed before they leave infested farms; farm equipment used on infested fields should be thoroughly cleaned before use on noninfested fields; soybeans should be inoculated with commercial inoculant only; produce should be marketed in clean containers.

(7) Everyone concerned is responsible for knowing and complying with regulations for controlling the soybean cyst nematode. Official information about the regulations and their application is available from USDA - ARS and State pest-control authorities.

OUTLOOK FOR NEMATODE RESEARCH AND CONTROL

Despite the enormous difficulties involved in fighting an insidious pest like the soybean cyst nematode, the record to date provides a strong basis for hoping that the destructive parasite can be held in check until more efficient methods for neutralizing its damage potential are developed.

(1) Enough has already been learned about the pest and its habits for effective control through quarantine regulations and sound cultural practices, particularly rotation to nonhost crops. That no evidence of infestation has been uncovered in any of the heaviest soybean-producing areas of the country is encouraging.

(2) Research is continuing to attack the soybean cyst nematode from many angles--and promises soon to yield more efficient weapons for controlling the pest. Presently, the outlook is brightest for developing resistance in a commercial soybean variety adapted to growing in most infested areas. Other possibilities for controlling or eradicating the nematode currently being studied include: New chemical treatments; cultural practices; and biological control by use of natural enemies of the nematode--such as, diseases caused by bacteria, fungi, and viruses; predators; and nematode-trapping fungi.

Until either a practical way of eradicating the soybean cyst nematode has been developed or improved resistant varieties of soybeans are available to growers, an effective containment program is essential. This means that for some time to come, heavy reliance must continue to be placed on quarantine regulations and rotation to nonhost crops for controlling the pest. Not only soybean growers but also farmers generally and consumers have a stake in preventing the heavy losses that would occur if the soybean cyst nematode were permitted to spread.

Growth Through Agricultural Progress